

Palmgren, Gaßner and the challenges of fatigue behavior of components at variable amplitudes

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The focus of this contribution is on the work of the German engineer Ernst Gaßner. He invented the first fatigue tests at variable amplitude loading and introduced the field of “Betriebsfestigkeit” to the engineering community.

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1 Introduction and historic context

The foundation of research on fatigue issues was laid by August Wöhler, who did fatigue experiments with constant amplitude loading at railway axles in the middle of the 19th century, [1]. Ideas on how to determine the fatigue life under variable amplitude loading however were discussed not before 1924, when the Swedish engineer Arvid Palmgren published the hypothesis of the *linear damage accumulation* for the first time, [2]. The linear damage accumulation is a tool to calculate the fatigue life of a component based on the knowledge of the fatigue life at constant amplitude loading (Wöhler-curve).

Palmgrens work – at least concerning this special aspect – remained unconsidered at that time and so the American Milton A. Miner came up with the same hypotheses in 1945, [3], which finally became very popular. It may be assumed that he did not know the work of Palmgren.

Little before Miner published this calculation approach to deal with the problem of variable amplitude loading, the German engineer Ernst Gaßner invented the first fatigue experiments at variable amplitude loading, [4, 5], which exceeded what had already been done in experiments with two or three different load levels of constant amplitude loading. The work of Gaßner that dealt with the development of different variable amplitude loading tests shall be in the focus of this contribution.

2 Gaßner’s tests at variable amplitude loading

In 1939 Gaßner was working for the German aviation program (Deutsche Versuchsanstalt für Luftfahrt, DVL). He states, [4]:

“For design of aircraft components it is [...] only possible to take into account the [load] frequencies, that actually occur [...]; this is because in aircraft design, apart from sufficient strength, also the least possible weight must be achieved.”

By this Gaßner puts lightweight design in the context of limiting the permissible life span of a component and thereby introduces the German term “Betriebsfestigkeit” (that might be translated inadequately to English by structural durability) to the engineering community.

The first tests under variable amplitude loading that Gaßner did were so called blocked program tests. Therefore, he used load spectra that were available from wind load measurements during flight operation, figure 1a¹. His aim was to test specimens with most realistically mixed loads but was limited by the available testing technology of that time. So he invented a test program that consisted of short blocks of constant amplitude loading that were mixed in ascending and descending order. In figure 1b one sequence, which Gaßner repeatedly applied to the specimen until failure occurred, can be seen. In this special case the sequence was designed so that twelve sequences need to be repeated to achieve the load spectrum of an airliner with 3000 operating hours from figure 1a. Gaßner presented the results of his experiments in diagrams that he called “scale lines”, figure 1c. This type of diagram is still used today (with a log-log scale) but is now called Gaßner-curve.

With the end of World War II the German aviation program was shut down and Gaßner founded his own lab for fatigue tests that later became founding member of the “Laboratorium für Betriebsfestigkeit” (LBF) in Darmstadt. During the time at LBF Gaßner developed a standardized form of his blocked program test (the LBF 8-step blocked program test, [6]). Since he himself had doubts about how realistic the load mixture in this type of test is, [4], he tried to introduce actually realistic loads into specimens. He achieved this goal by mounting a testing machine on the rear seat of a car and coupled the load train of the testing machine to the rear axle of this car. So he was able to test specimens under most realistic loads. This type of tests was called *service load tests*, [7, 8]. With the introduction of servohydraulic test equipment in the 1960s it was possible to apply load-time series with cycle by cycle load changes and with that the same realistic loads as in service load tests – but much cheaper and faster within the lab. These tests were called service load duplication tests, [7, 8].

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¹ For reasons of comprehensibility, the important aspects of the illustrations were redrawn over the original ones.

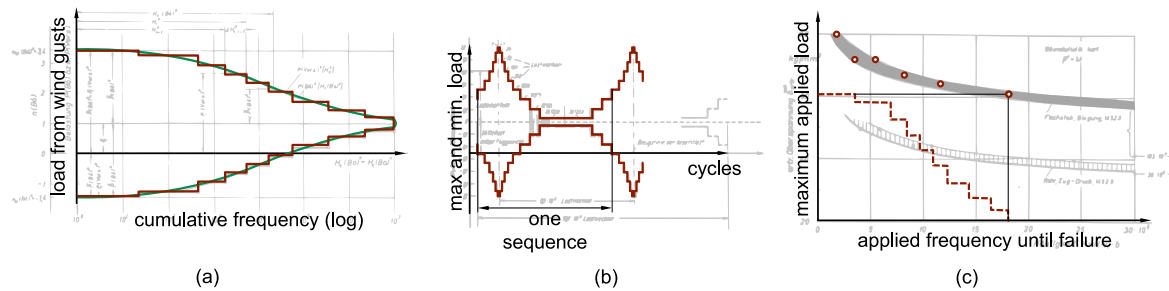


Fig. 1: 9-step blocked program test, [4,5]. (a) load spectrum, (b) test load sequence, (c) visualization of test results

3 Comparison of test results

After it was possible to generate test results with the three types of tests, mentioned above, blocked program tests, service load tests and service load duplication tests, Gaßner and his co-worker W. Lipp compared the different results, figure 2, [7,8] and concluded: 1. Service load tests and service load duplication tests are in good agreement. Service duplication tests therefore may be used for component approval. 2. Blocked program tests lead to life spans that are higher than the ones from service load tests (factor 2 – 3). Blocked program tests therefore should not be used for component approval.

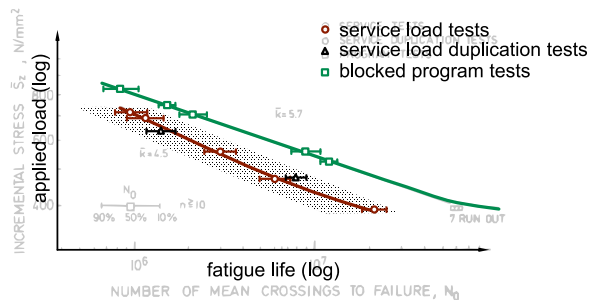


Fig. 2: Comparison of results from blocked program, service load and service load duplication tests [8]

4 Conclusion

Gaßner founded the field of “Betriebsfestigkeit” and invented important tests in this field: The blocked program, the service load and the service load duplication test. While he was convinced of his work, he wasn’t too keen to question his own results and came to the conclusion that his early invention, the blocked program test, was not suitable for component approval and yet found the practical alternative of service load duplication tests.

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